Transformer industry productivity slows

Annual productivity increases averaged 2.4 percent during 1963–79, slowing since 1972 to 1.5 percent; computer-assisted design and product standardization aided growth in output per employee-hour

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Productivity in the transformer industry increased at an average annual rate of 2.4 percent from 1963 to 1979, about the same as the 2.5 percent-rate shown by all manufacturing establishments.[1] The growth in productivity in the transformer industry was the result of output gains averaging 3.7 percent and advances in employee-hours, averaging 1.3 percent. (See table 1.)

This growth occurred because of many factors, most importantly the change to a straight-line production process incorporating assembly line techniques because of the expanding use of computers. Another reason for the rise in productivity was a rapid increase in capital expenditures per employee in the mid-1960's. These purchases of new plant and equipment, coupled with output growth, produced operating efficiencies.

The long-term productivity trend can be broken into two distinct periods: from 1963 to 1972, productivity increased an average of 3.8 percent; from 1972, it rose only 1.5 percent a year.

An expansive period, 1963–72

As productivity grew in the transformer industry from 1963 to 1972, output per employee-hour for all manufacturing increased too, but at only a 2.3-percent rate. Output in the industry showed gains averaging 7.7 percent annually; employee-hours advanced only 3.7 percent.

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Short-term changes in productivity are frequently linked to changes in output levels. Very large increases in transformer industry output occurred in 1964 (13.7 percent) and 1965 (18 percent). These jumps in output were associated with large gains in productivity, 8.6 and 9.0 percent. Output rose every year during 1963–72, and productivity fell only twice.

During this extended period of output growth there were significant changes in technology and production flow leading to a higher rate of productivity gain than in the more current period. The sustained output growth enabled companies in the industry to invest in more efficient plant and equipment and to hold on to experienced, productive employees.

There were several reasons for this rapid output growth. Demand from electric utilities grew because they were making extensive additions to their generating capacities, requiring more transformers. Furthermore, regional pool formation required interconnections between power companies, also increasing demand for transformers. Installed generating capacity in the United States increased 83 percent between 1963 and 1972; and additions to this capacity rose an average of 9.3 percent a year.[2] Overall economic growth aided transformer markets during this period. For example, distribution transformers were increasingly needed as new electrical lines were extended into undeveloped neighborhoods. Permits for new housing were issued at a rate of 4.8 percent annually from 1963–72. (For the entire period, 1963 to 1979, they were issued at a rate of 0.9

Table 1. Productivity and related indexes for transformers
[1977 = 100]

Year	Output per employee-hour			Output	Employee-hours		
	All employees	Production workers	Nonproduction workers		All employees	Production workers	Nonproduction workers
1963	67.5	67.6	67.1	51.9	76.9	76.8	77.3
1964	73.3	71.9	77.0	59.0	80.5	82.1	76.6
1965	79.9	77.0	87.4	69.6	87.1	90.4	79.6
1966	75.8	72.9	83.7	74.1	97.7	101.7	88.5
1967	75.5	73.0	82.1	79.5	105.3	108.9	96.8
1968	80.2	77.5	87.1	85.5	106.6	110.3	98.2
1969	88.6	85.1	97.7	92.3	104.2	108.5	94.5
1970	89.1	84.9	100.6	96.7	108.5	113.9	96.1
1971	94.4	90.1	105.8	97.8	103.6	108.5	92.4
1972	98.1	94.1	109.1	104.5	106.5	111.1	95.8
1973	96.9	91.5	112.4	115.7	119.4	126.5	102.9
1974	92.7	88.5	104.2	113.0	121.9	127.7	108.4
1975	89.3	92.0	83.9	85.5	95.7	92.9	101.9
1976	90.1	92.0	85.9	86.2	95.7	93.7	100.3
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	103.4	102.1	106.7	106.7	103.2	104.5	100.0
1979	108.3	105.7	114.6	112.5	103.9	106.4	98.2
	Average annual rates of change (in percent)						
1963–79 .	2.4	2.6	2.1	3.7	1.3	1.1	1.6
1963–72 .	3.8	3.4	4.9	7.7	3.7	4.1	2.7
1972–79 .	1.5	2.1	([1])	−0.3	−1.8	−2.3	0.3

[1] Less than 0.05 percent.

percent). Demand from industry grew. Industry uses transformers to step down distribution voltages for the operation of machinery. Industrial production advanced 4.6 percent a year.[3] Growth in output of specialty transformers, such as fluorescent lamp ballasts, is tied to new industrial and commercial construction. This construction was done at a rate of 3.7 percent annually. Increased demand for such specialty products aids productivity growth because long runs of similar items reduce downtime for such operations as resetting machines for differing models.

Another reason for industry output increases during 1963–72 was growth in the replacement market for distribution transformers. The capacity of these transformers improved during this period. Replacing transformers with upgraded units tended to increase electrical system network reliability.

While the output of the transformer industry was increasing at nearly 8 percent a year, employee-hours grew at the lower rate of 3.7 percent. Production worker-hours advanced more rapidly than the all-employee average, 4.1 percent annually. Nonproduction worker-hours increased at only 2.7 percent. This lower rate of growth in nonproduction worker-hours can be attributed to increased use of computer-assisted design, which sharply reduced the number of engineering hours required to design power transformers.

Despite the general growth trend of the period, there were 2 years of productivity declines—5.1 percent in 1966 and 0.4 percent in 1967. Output showed healthy increases in both of these years (6.5 and 7.3 percent); however, employee-hours increased more than output (12.2 and 7.8 percent). This was the result of strained capacity in the industry. By 1966, there had been several years of large output increases (in 1964, 13.7 percent, and in 1965, 18 percent) and the industry was experiencing shortages of skilled labor, materials, and components, resulting in productivity falloffs.[4]

Industry capacity began expanding in mid-1967, relieving some of these constraints on productivity growth.

A jump in productivity of 10.5 percent in 1969 was the result of a fairly sizable increase in output of 8 percent, while employee-hours fell 2.3 percent. One of the largest companies in the industry had a major and lengthy strike that year, resulting in the decrease in employee-hours. However, competitors were able to take up the slack without major increases in their own work forces.

Slow-up in the 1970's

As noted, productivity increased only 1.5 percent a year in the more recent period, 1972–79. Output decreased an average of 0.3 percent annually, heavily influenced by the 1974–75 recession. A small decline in output in 1974 of 2.3 percent was followed by a much larger output drop in 1975, 24.3 percent. Demand from major markets for transformers showed deterioration in 1974 and 1975. Industrial and commercial construction dropped 8.6 percent in 1974 and 17.6 percent in 1975. The number of new housing permits issued began decreasing in 1973, falling 18.3 percent. This decline continued during the recession of 1974–75. The number of permits issued fell 40.5 percent in 1974 and 12.7 percent in 1975. Industrial production also dropped, 0.4 percent in 1974 and 8.9 percent in 1975. Although electrical capacity continued to increase, the amount of the gains in both these years was lower than in 1973.

The 1974–75 recession hit the industry sharply. In 1975, at least three large establishments were closed and most manufacturers cut back on their work force. Despite this, employee-hours declined less than output, and productivity fell 3.7 percent. On the other hand, the economic slowdown of 1970–71 did not cause any actual decline in either productivity or output. Although the latter increased only 1.1 percent in 1971, the industry cut back employee-hours 4.5 percent; productivity rose 5.9 percent.

Most of the markets for transformers have shown declines or slowdowns in the more recent period, resulting in the overall falloff in output of 0.3 percent per year. Additions to installed generating capacity decreased at an average of 8.4 percent a year between 1972 and 1978. The number of new housing permits authorized fell at a rate of 2.0 percent. Industrial and commercial construction also declined, by 0.3 percent. The only positive indicator was industrial production which increased 3.1 percent annually, substantially slower than the earlier 4.6-percent rate.

Other factors which adversely affected demand and productivity during this period included the shortage and increased price of petroleum products. The rate of increase in electrical energy sold has slowed considerably. Utilities have required fewer additional transformers. Also, many of the insulating fluids used by the industry are petroleum based, and spot shortages occurred during the oil boycott, adversely affecting the production process.

Some shifts in use of materials which increased labor requirements temporarily in the industry included a changeover from copper to aluminum windings used in transformers. For low-voltage applications, this occurred in the mid-1960's. Later, aluminum began to be used in high-voltage applications. This changeover did not begin until the early 1970's; it required modifiying design libraries in the computer. Also, different types of connectors had to be designed to connect the copper terminations to the aluminum windings.

Employment rises faster than hours

Employment in the transformer industry has been increasing more quickly than hours. Although employee-hours rose 1.3 percent between 1963 and 1979, employment advanced slightly more, 1.4 percent. Average weekly hours of production workers decreased 0.3 percent a year.

The number of production workers has increased an average of 1.4 percent annually, and their hours, 1.1 percent. At the same time, nonproduction workers and their hours have shown advances of 1.3 and 1.6 percent. The net result is that output per production worker-hour, at 2.6 percent, has been rising faster than output per all employee-hour. The opposite is true of output per nonproduction worker-hour, which shows an average annual gain of 2.1 percent.

Industry structure

The transformer was invented in the late 1800's. Since then, the industry has been dominated by a few large companies. However, many small firms have managed to succeed by specializing in one product rather than offering a complete array. The concentration ratio for the industry (the proportion of shipments accounted for by the four largest companies) fell from 68 percent in 1963 to 59 percent in 1972.

The products made in this industry cover a broad spectrum of sizes and markets. Power and distribution transformers, used by utilities and industry, made up 62 percent of transformer shipments in 1979. Fluorescent lamp ballasts, most of which are installed in new commercial and industrial buildings, accounted for 13 percent of these shipments; other specialty transformers made up 17 percent. This latter category consists of toy and doorbell transformers, machine tool control transformers, and other miscellaneous items. The fourth category; power regulators, boosters, reactors, and other transformers; accounted for 8 percent of 1979 shipments.

About half of the manufacturing facilties are located in the Middle Atlantic and East North Central parts of the country. There has been growth in the number of plants in the South and South Central States. Combined, they accounted for 15 percent of the establishments in 1963 and 25 percent in 1977.

The average number of workers in a transformer plant, 155, is about three times that for total U.S. manufacturing, 53. In 1977, 41 percent of the industry's employees worked in establishments with 1,000 employees or more. At the total U.S. manufacturing level, this was true for only 29 percent of the employees.

Technology and capital expenditures

Capital expenditures per employee in the transformer industry increased at a lower rate than the all-manufacturing average between 1963 and 1979. While these expenditures rose an average 8.8 percent a year at the total manufacturing level, the transformer industry has had gains of only 5.9 percent.

The number and hours of nonproduction workers had a lower rate of growth than those of production workers in the 1960's because of the increased use of computer-assisted design. Power transformers must be custom designed and are generally sold by bid. Custom designing is necessary because each individual community or plant has its own specific electrical needs and standards. These include the size of the transformer and the capacity which will be needed. In addition, visibility and noise levels must be considered.

Because of the need for custom design, orders for these types of transformer units must be submitted up to a year in advance. In the late 1950's, the industry began to use computers to do routine engineering work. Manual transformer design required an engineer and several assistants and took months. Once the computers were programmed, they could do the same job in a few days.

In the process of preparing a bid for power transformers, a company must complete about 50 percent of the design work. Although several bids will be submitted, only one firm will receive the contract. Prior to the computerization of the design work, many months of engineering time went into every contract. Computers reduced this effort substantially.

Most of the larger firms in the industry had already made the changeover to computer-assisted design by

1963. However, some of the productivity gain came about as the smaller companies began adopting the procedure. In addition, productivity growth was realized throughout the industry during this period because the technology became more efficient as the design libraries were expanded to cover additional variables. Also, the computers were more fully utilized to handle larger numbers of tasks related to transformer design. In designing a transformer, the computer chooses the parts. It was possible to program the computer to go one step further and do the cost estimates for parts. It can also be programmed to make drawings for the shop floor, decreasing the amount of labor required to draft them by hand.

An important by-product of computer design was that, in order to make the system work, it was necessary to standardize the product. Standardization allowed the industry to change from job shop procedures to assembly line manufacture, using a more efficient factory layout. This was the primary force behind accelerated productivity growth during the late 1960's.

In the job shop, each item was designed and built individually. Because there was little standardization of the product, manufacturing machinery was not automated. However, following standardization, the use of more automatic equipment became possible. Transformer tanks, the metal enclosures which hold the transformer and insulating oil, could be made in a few basic styles. This fabrication was done using increasingly available numerically controlled machinery to cut, bend, punch, and drill the metal. This same machinery is also used to cut strips of metal to the size needed to make the transformer core, which is composed of layers of thin metal pieces that form the central functioning part of the transformer.

As the industry's manufacturing machinery became more complex, more automatic controls were built in, leading to less operator setup and running time. For example, use of punched tape on numerically controlled machines freed the operators to run more machines in the same amount of time.

Bushings, the insulators used to protect the power lines where they enter the transformers, were originally made of porcelain. In the late 1960's, there was a switch to epoxy. Because of this change in material, greater design flexibility in transformers was possible. Also, labor requirements were reduced because fewer parts needed to be assembled.

Additional technological advancement

More recent changes in technology have included equipment to improve the impregnation and dryout of transformer insulation systems and assemblies. There has also been the introduction of machinery for the automatic coating and drying of laminations.

In addition to their contribution in design and accounting work, computers are also being used on the factory floor to monitor work as it flows through the workplace. Having been used to design the product and produce the drawings, computers are also used to set up the machinery for production. They schedule work, load machinery, and make sure that necessary materials are on hand. The inventory control functions of computers have reduced the need for clerical workers. Computers keep track of inventory, estimate the needs for materials, and initiate orders for materials which are in short supply by printing purchase orders.

The changeover to new factories which use straight-line production flow has enabled transformer manufacturers to install material handling systems which have increased productivity considerably. Power transformers are heavy; they are carried through the workplace by mobile and bridge cranes, roller and belt conveyors, fork trucks, and monorail systems. Drag chain systems, installed in the floor, carry transformer assemblies on dollies. One spokesman claimed that straightening the assembly line can reduce the number of times each transformer must be moved during assembly by 75 percent, and total manufacturing time by 25 percent.[5]

There have also been a few changes in fluorescent lamp ballasts which have contributed to productivity growth. Many of these changes were small. Because of frequent design changes, it has not been feasible to mechanize the entire ballast manufacturing operation. By 1963, core winding was mechanized. The innovation was the introduction of multiple winding machines which enabled one worker to handle many more coils than before.

Changes have been made in transformer electrical connections which have lowered labor requirements. Originally, connections were hand-soldered. Now, most are either brazed, in which the copper pieces are placed together and run under a torch, or wave-soldered, which eliminates cleaning operations and is semiautomatic.

Looking ahead

Offsetting trends in demand for transformers and possible changes in product design will probably lead to continued modest advances in productivity. Electric utilities, by far the largest customer of the industry, are making less investment in transmission and distribution. As consumers and industry attempt to save on the use of electricity in the face of rapid rate increases, utilities have experienced over-capacity and low growth in peak demand. Housing starts in the near future are also uncertain, affecting the market for distribution transformers.

The market for specialty transformers poses other problems, with a resultant impact on output growth.

Because of increasing costs and spot shortages of these items, equipment manufacturers have become disenchanted. Many have begun to either make their own transformers or design their equipment to eliminate or cut down the number of transformers needed, or both.

Offsetting this trend to some extent, a new type of fluorescent lamp ballast has been designed using solid state technology and transitors. The cost of this type of unit is currently much higher than a conventional unit, resulting in little use of it.

One major technological revolution in the industry, already in the testing phase, is the use of metallic glass in transformers. This material, which could replace conventional steel in many applications, has many advantages in transformer operation. Metallic glass is a special type of steel which would operate at significantly lower temperature than present types of transformers, leading to their complete change. If the use of metallic glass becomes feasible and the industry shifts over to it, the short-term effect could be a drop in productivity. Its use would require complete redesign of transformers, new machinery, and retraining of the work force. However, in the longer run, if manufacturers invest heavily in new equipment which would tend to be more automatic, the use of this material could lead to productivity growth. □

FOOTNOTES

[1] Average annual rates of change are based on the linear least squares trends of the logarithms of the index numbers. The transformer industry is designated industry 3612 in the *Standard Industrial Classification Manual 1972*, issued by the Office of Management and Budget. The industry comprises establishments primarily engaged in the manufacture of power, distribution, instrument, and specialty transformers. The indexes for this industry will be updated and included in the annual BLS bulletin, *Productivity Indexes for Selected Industries*. A technical note describing them is available upon request.

[2] Based on data from the Federal Power Commission as cited in the *Statistical Year Book of the Electric Utility Industry*, various issues, put out by the Edison Electric Institute. In addition to electric utilities, the numbers include the capabilities of industrial, mine, and railway electric power plants.

[3] *Industrial Production 1976 Revision* (Washington, Board of Governors of the Federal Reserve System, Division of Research and Statistics, Business Conditions Section, December 1977). This has been updated with press releases, which were also used.

[4] Howard E. Way, "Power, Distribution and Specialty Transformers," *U.S. Industrial Outlook 1966* (U.S. Department of Commerce, Business and Defense Services Administration, December 1965), Ch. 19, pp. 129–131.

[5] "GE Dedicates Major Facility for Power Transformer Work," *Electronic News*, June 24, 1968, p. 37.

APPENDIX: Measurement techniques and limitations

Indexes of output per employee-hour measure changes in the relation between the output of an industry and employee-hours expended on that output. An index of output per employee-hour is derived by dividing an index of output by an index of industry employee-hours.

The preferred output index for manufacturing industries would be obtained from data on quantities of the various goods produced by the industry, each weighted (multiplied) by the employee-hours required to produce one unit of each good in some specified base period. Thus, those goods which require more labor time to produce are given more importance in the index.

In the absence of adequate physical quantity data, the output index for this industry was constructed by a deflated value technique. The value of shipments of each of the various product classes was adjusted for price changes by appropriate Producer Price Indexes to derive real output measures. These, in turn, were combined with employee-hour weights to obtain the overall output measure. These procedures result in a final output index that is conceptually close to the preferred output measure.

Employment and employee-hour indexes were derived from BLS data. Employees and employee-hours are each considered homogeneous and additive and thus do not reflect changes in the qualitative aspects of labor, such as skill and experience.

The indexes of output per employee-hour do not measure the specific contributions of individual factors, such as that of labor or capital. Rather, they reflect the joint effect of many factors; for example, changes in technology, capital investment, capacity utilization, plant design and layout, skill and effort of the work force, managerial ability, and labor-management relations.